FINAL REPORT

SHALLOW INJECTION OF LIQUID HOG MANURE ON GRASSLAND

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Prepared by: PAMI

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Final Report

Shallow Injection of Liquid Manure on Grassland

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Acknowledgements

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1. Summary

The project entitled "Shallow Injection of Liquid Manure on Grassland" has been successfully completed.

The results from the testing have shown benefits to injecting hog manure into forages in the form of increases in seed and forage yield. The increase in yield was found at all levels of application. The most promising rate was 74,000 L/ha (6,600 gal/acre) applied every second year. This application rate showed excellent yield increases over the control plot, in years following application of manure. There were also satisfactory results in years between applications. The results were consistent over each forage variety and over the three years of testing.

The tests showed that there were only small effects to the forage quality. In most of the replications in each year the crude protein, neutral dietary fiber, and acid detergent fiber showed no significant differences within each plot.

One concern that arose from this study is the level of nitrate concentration in the forages following manure application. High nitrate concentrations in feed have been implicated in the sudden death of livestock. The results of this study showed an increase in nitrate levels in the first year, following application of manure at the Russian wild rye site with spring application. This result was found only with Russian wild rye grass and only spring manure application, but testing was not extensive enough to ensure that this is the only practice that could produce toxic feed. **Based on these very limited results, producers should use caution when spring applying swine manure to forages.**

This study showed only slight increases in soil nutrient levels each year. Soil tests showed that even with the high rates of application, there were moderate levels of nutrients in the top 30 cm of the soil profile. The tests also showed no increases in nutrient levels below the 30 cm point which indicated no leaching of the manure.

The machine used for injection in this project was a "Greentrac" manure injection machine, which has an injector designed for use in grassland. It is manufactured in Ireland and popular in Europe. They now have a North American distributor and have donated the use of the machine for the duration of this project. The Greentrac performed very well, with little surface disturbance and good coverage of the injected manure. Bourgault Industries now produces an injector that can be used for grassland injection.

2. Technical Report

2.1 Background and Objectives

The changes in the agricultural economic situation along with changes in world food demand have resulted in a new farm model. The Canadian Prairie farmer has responded to this challenge by producing new crops or increasing existing production as demanded by the consumer. Increased world demand for livestock products has stimulated a plan in Saskatchewan to increase hog production over the next several years. One obstacle to the development of the hog industry will be the availability of land for the application of liquid hog manure. Shallow injection of hog manure on grasslands is one possible solution to this problem.

Hog manure has the potential to provide fertilizer to many acres of grassland, which are currently under fertilized. Injecting hog manure to grassland could provide extra acreage for manure application, and could also improve grass production on these lands. Hog manure can provide the nutrient requirements of the grass, and may be available at little or no cost to the owner of the grassland. This would enable the development of hog production in areas where annual cropland is unavailable for spreading manure. Grassland can be injected during the summer so that the manure application period can be extended from the current spring and fall periods. The increase in conservation tillage and continuous cropping has made summer fallow acres, where summer application has previously taken place, less available or non-existent in many areas.

The objective of this project was to demonstrate to producers the potential of using shallow injection to apply liquid hog manure to grassland in Saskatchewan, to determine the effect hog manure has on forage yield, quality and nitrate levels, and the effect on soil nutrient levels under various application rates.

2.2 Project Activities

This study was conducted over a three year period. The Greentrac injection system, using coulter type openers was used to inject liquid hog manure 10 to 13 cm (4 to 5 inches) into mature grass stands. The coulters were arranged to inject the manure at a row spacing of 30 cm (12 inches). Three different types of crop types were chosen for this study; crested wheatgrass in Englefeld, SK, smooth bromegrass/alfalfa in Burr, SK, and Russian wild rye in Lanigan, SK. The experimental design was a randomized complete block design, which was replicated four times. Included in this were two control plots. The first control plot was an undisturbed check. The second control was

a disturbed check, which had the injector pass over it without any manure injection. This check was worked just as the other injected plots were, each time an injection treatment was done. The sites at Englefeld and Burr had the initial manure application in September of 1997 at application rates of 37,000 L/ha (3,300 gal/acre), 74,000 L/ha (6,600 gal/acre), and 148,000 L/ha (13,200 gal/acre) **(Table 1, Appendix I)**. The following spring, a third site at Lanigan was added with the same rates applied. In 1998, the second year of the project, a second rate of 37,000 L/ha was applied to the plots. The 74,000 L/ha rate and the 148,000 L/ha rates were not applied in the second year. In 1999, the third year of the project, a third rate of 37,000 L/ha was applied along with a second rate of 74,000 L/ha. The high rate of 148,000 L/ha was only applied in the first year.

Table 1. Application Sequence.

Location/Crop	1997		1998		1999	
	Spring	Fall	Spring	Fall	Spring	Fall
Englefeld, SK Crested Wheatgrass		37,000 L/ha 74,000 L/ha 148,000 L/ha		37,000 L/ha		37,000 L/ha 74,000 L/ha
Burr, SK Smooth Bromegrass/Alfalfa		37,000 L/ha 74,000 L/ha 148,000 L/ha		37,000 L/ha		37,000 L/ha 74,000 L/ha
Lanigan, SK Russian Wild Rye			37,000 L/ha 74,000 L/ha 148,000 L/ha	37,000 L/ha		37,000 L/ha 74,000 L/ha

In each of the three years, at each of the sites, three 10 L samples were taken from the applicator during application and analysed for nutrient content **(Tables 2 to 4, Appendix I)**

Soil samples were taken from the plots each April and September at 0 to 30 cm and 30 to 60 cm. Samples were analysed for ammonium, nitrate, and extractable phosphorus and potassium **(Tables 5 to 7, Appendix I)**.

Grass samples were collected, by the Saskatchewan Forage Council, from each plot in mid-June to early July in 1998, 1999, and 2000, as soon as heading was complete. Four samples were taken, each covering an area of 1.2m x 6m, cut from each plot and weighed to determine the wet weight yield for each plot. In addition, samples were collected at random from each plot during harvesting and used to correct yields to a dry weight basis. They were also analysed to determine the crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and nitrate content of the forage for each treatment **(Tables 2 to 4, Appendix I)**.

In August 1998, two, one-quarter meter samples were collected in each plot from the Englefeld site. Samples of crested wheatgrass were used to determine the seed yield (**Tables 2 to 4, Appendix I**). This was repeated in 1998 and 1999 with three, one-half meter square samples.

2.3 Results and Conclusions

2.3.1 Yield Data

Yield data gathered over the trial period clearly shows a forage yield benefit to grasslands from manure injection. In 1998, all three forages appeared to respond best to treatments in the range of 100 – 200 kg N/ ha (corresponding to the 37,000 and 74,000 L/ha manure treatments) (**Tables 2 to 4, Appendix I**). At the 74,000 L/ha application rate, crested wheatgrass yielded 4390 kg/ha, compared to 1000 kg/ha on the undisturbed check. The smooth brome/alfalfa mix yielded 2760 kg/ha with the same treatment, compared to 1650 kg/ha on the undisturbed check. Russian wild ryegrass produced a modest 49% increase over the undisturbed check at the 74,000 L/ha rate.

In 1999, the three forage crops again displayed positive forage yield results from manure injection. Crested wheatgrass showed the most dramatic increase in yield at the 37,000 L/ha application rate, producing 4460 kg/ha in comparison to 1400 kg/ha on the undisturbed check. In comparison, the 74,000 L/ha and 148,000 L/ha plots each produced approximately 3000 kg/ha. The smooth brome grass / alfalfa yields were significantly higher in year two. The 37,000 L/ha and the 148,000 L/ha treatment plots yielded 10,600 and 10,000 kg/ha respectively, while the 74,000 L/ha treatment plot yielded only slightly less at 8820 kg/ha. Both the undisturbed check and the disturbed check also yielded higher in year two, increasing to 5010 kg/ha and 4300 kg/ha respectively. The rise in yield on the check plots may indicate that growing conditions in 1999 were favorable for smooth brome/alfalfa. Russian wild rye grass forage yields showed a good response to the treatments as yields on all treated plots were up to between 5000 – 5500 kg/ha, up from 2600-3400 kg/ha in 1998. Control plots for Russian wild rye grass were up slightly from 1998, at approximately 2200 kg/ha.

Year 2000 was the last year of the testing. It proved to be a poor year, as all the plots had reduced yields over the previous two years. All three varieties of grass again responded well to the 37,000 L/ha treatment and the 74,000 L/ha treatment. The effect of the 148,000 L/ha treatment in year one appeared to taper off by Year 3, as these test plots produced reduced yields.

Results over the three-year study have shown benefits in increasing the forage yield without negative mechanical effects from the injector. The first year results showed the highest yielding plots were from an application of 74,000 L/ha. Applying rates at the highest level, 148,00 L/ha, showed a lesser degree of yield increase along with an excess level of nitrate in Russian wild grass in comparison to the other application levels. Residual affects from the application of high rates in the first year carried through to the second year and even to the third with the 148,000 L/ha rate. The application of hog manure on forages showed significant yield increases in all cases as all plot results had higher yields compared to the control. From the results of this study the most economical application strategy would be to apply 74,000 L/ha (6,600 gal/acre) every other year.

2.3.2 Nitrogen Availability

Another added benefit of manure application was the effect the manure had on increasing the nitrogen availability in the soil. Grass yield and protein content increases are due to the effect of the hog manure increasing the soil nitrogen availability, although it is possible that other nutrients in the manure, including phosphorus and potassium may also have contributed to the yield increases. All the test plots showed significant plant nitrogen uptake, and in general, the amount of nitrogen uptake tended to increase with the increasing hog manure application rate. However, in 1999 the 37,000 L/ha application rate showed a large increase in nitrogen uptake by the Crested Wheatgrass and the Russian wild rye, compared to the other application rates.

2.3.3 Forage Nitrate Content

Forage nitrate content was measured each year (**Tables 1 to 3, Appendix I**). Forage nitrate content is an important consideration when feeding livestock. Generally, a nitrate content of 0.0 to 0.15% is considered to be safe under all conditions. At levels of 0.15 to 0.45% the feed may become dangerous, and at levels above 0.45%, the feed is potentially toxic and is not recommended for use as feed. Samples from the test plots found that the smooth brome/alfalfa remained within the acceptable levels for all application rates each year. The Russian wild rye grass, however, had nitrate content well above the acceptable levels in 1998. In 1999 and 2000, all the test plot samples were well within acceptable levels, including the Russian wild rye grass. The Russian wild rye grass nitrate levels in 1998 may be related to the characteristics of the plant, which tends to be a very basal growth habit, with many large dark green basal leafs. These large succulent leafs can accumulate nitrates, especially when the environmental conditions are right. Crested wheatgrass and smooth brome / alfalfa, on the other hand, have a more upright growth pattern, and have a higher nitrogen demand, which will result better nitrogen assimilation.

The Lanigan Site was also the only test of spring application. Other applications were done in fall. Tests of spring application must be done with other varieties to ensure that proper guidelines for safe timing of grazing can be developed. It may be that timing of application is crucial to control nitrate levels.

2.3.4 Soil Sampling Results

Soil samples were taken in spring and fall of each year (**Tables 5 to 7, Appendix I**). Samples were taken from depths of 0 to 30 cm and 30 to 60 cm. They were tested for nitrogen, phosphorus, and potassium.

In 1998 and 1999, samples taken in spring showed that the hog manure application had produced a large increase in plant available inorganic nitrogen. This increase was found almost exclusively in the 0-30 cm range, with little effect on available N being found in the 30-60 cm range. Any ammonium nitrogen applied as hog manure would have been taken up by the grass roots, used by the soil microorganisms, or may have been lost to volatilization. Some of the organic N added in 1997 and 1998 would be mineralized, while some would remain as organic N at the end of the season.

Fall manure treatments did not significantly alter the inorganic N left in the soil for 1998, when compared to the control plots for crested wheatgrass and smooth brome/alfalfa plots. Russian wild rye did produce substantially higher inorganic N levels in the fall at the 148,000 L/ha application rate, although the inorganic N was still less than 100 kg/ha. At no time was there any evidence of nitrogen leaching below the 0-30 cm depth. Total N had actually reduced to less than 20 kg/ha by the fall of 1999. There was an increase of spring available N in 2000 related to the manure application from the previous fall.

The manure analysis showed low amounts of P applied as manure, which resulted in low soil test levels. Extractable K increased because of the high amount of K applied as manure. However, the extractable K is not sensitive enough to indicate significant differences in the majority of cases.

Other properties of the soil, in particular electrical conductivity and soil pH were not affected by the manure application in this testing. However, hog manure applied to the land should routinely be tested for salt content and concentrations as part of the manure analysis. In addition, fields should be monitored for salt and other nutrient concentrations on an on-going basis.

In conclusion, this study has shown the benefits in applying hog manure on forages. The shallow injection equipment places the manure where the plants can utilize it, without any damaging mechanical effects. The nutrients in the manure are beneficial in

increasing the yields of forages without any negative affects to the quality, providing it can be done in a manner that nitrate levels can be managed. There are concerns with higher nitrate levels in the feed; however, with further research with varieties, timing of application, and limits on application rates, this should be manageable. The study also showed that levels on nutrients in the soil are not dramatically increased and do not leach to lower levels in the soil profile. The application of hog manure on forages is an alternative that can have beneficial effects for the livestock industry in economic savings for the cost of fertilizer, in increased seed and feed production, and as an avenue for the disposal of manure for an intensive livestock operation.

2.4 Indications of Further Development

A manure injector system that will work well in forage and pasture has been developed by Bourgault Industries of St. Brieux and is now available. Some hog producers are now injecting manure on hay and pasture areas.

It is important that appropriate testing is carried out to ensure that forage nitrate levels are not exceeded, particularly with spring and summer application of manure.

4. Equipment

No equipment has been purchased for this project. PAMI equipment has been used and the Greentrac injection machinery was donated.

5. Project Photos

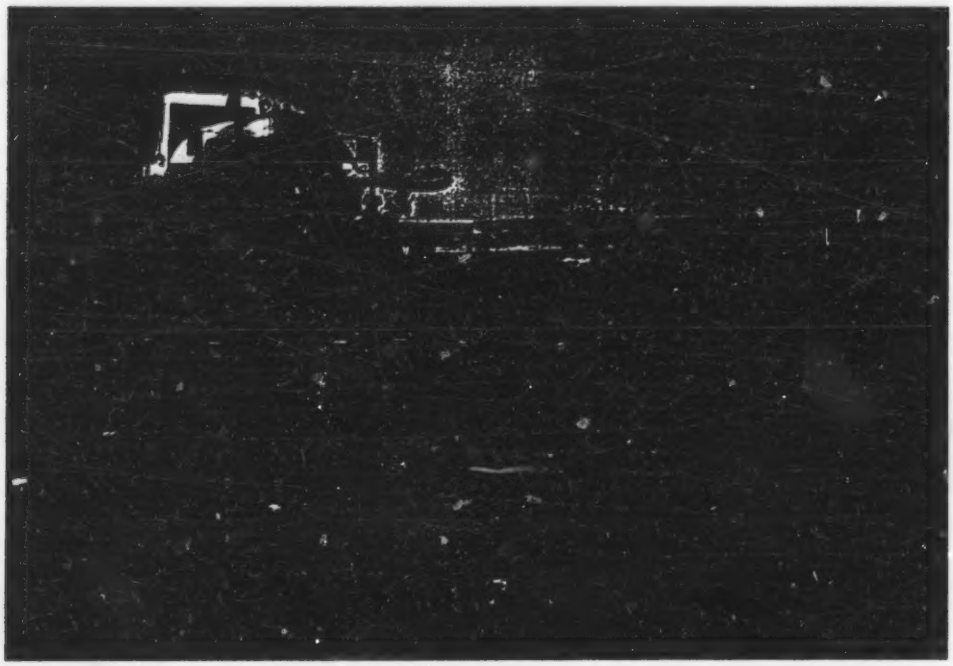

Figure 1. Greentrac Injector Applying Liquid Hog Manure on Forages.

Figure 2. Englefeld, June 24, 1998. Crested Wheatgrass—Disturbed Check-Left; Undisturbed Check-Right.

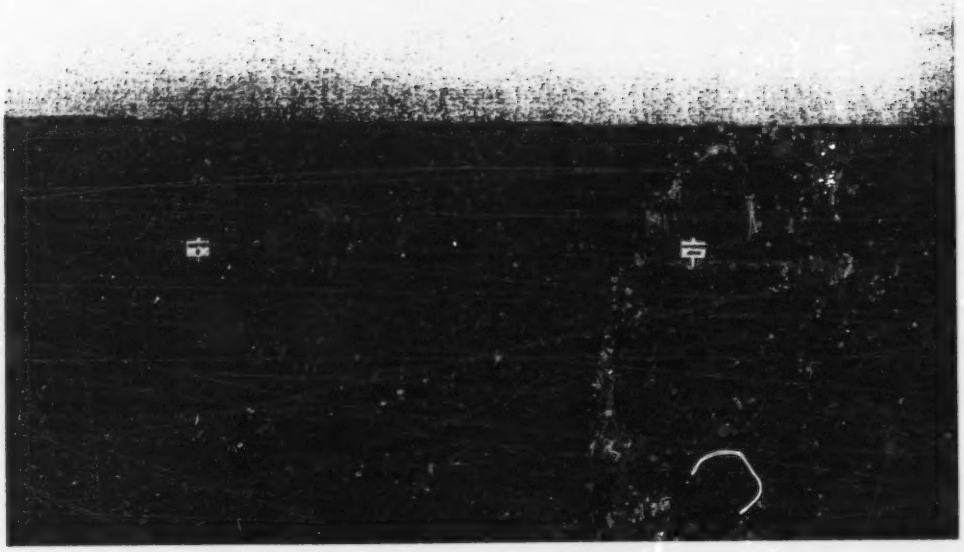

Figure 3. Englefeld, June 24, 1998. Crested Wheatgrass—Close-up of 200 lb/ac-Left; Disturbed Check-Right.

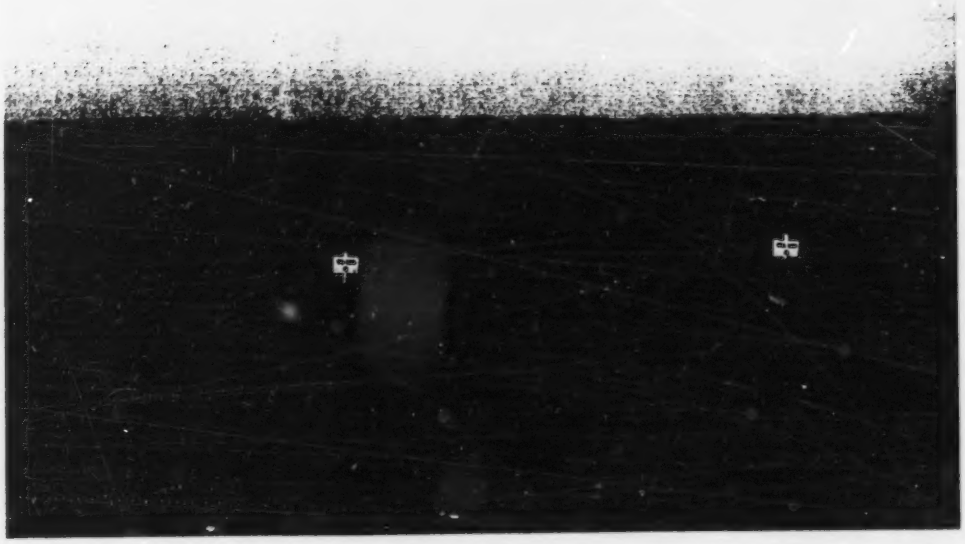

Figure 4. Englefeld, June 24, 1998. Crested Wheatgrass—50 lb/ac-Left; 100 lb/ac-Right.

Figure 5. Englefeld, June 24, 1998. Crested Wheatgrass—200 lb/ac-Left; Disturbed Check-Right.

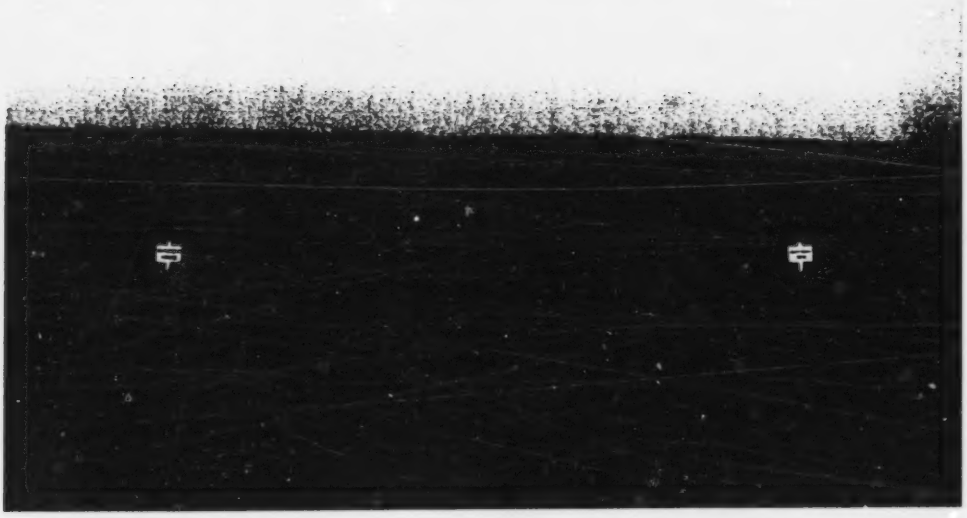

Figure 6. Englefeld, June 24, 1998. Crested Wheatgrass—100 lb/ac-Left; 200 lb/ac-Right.

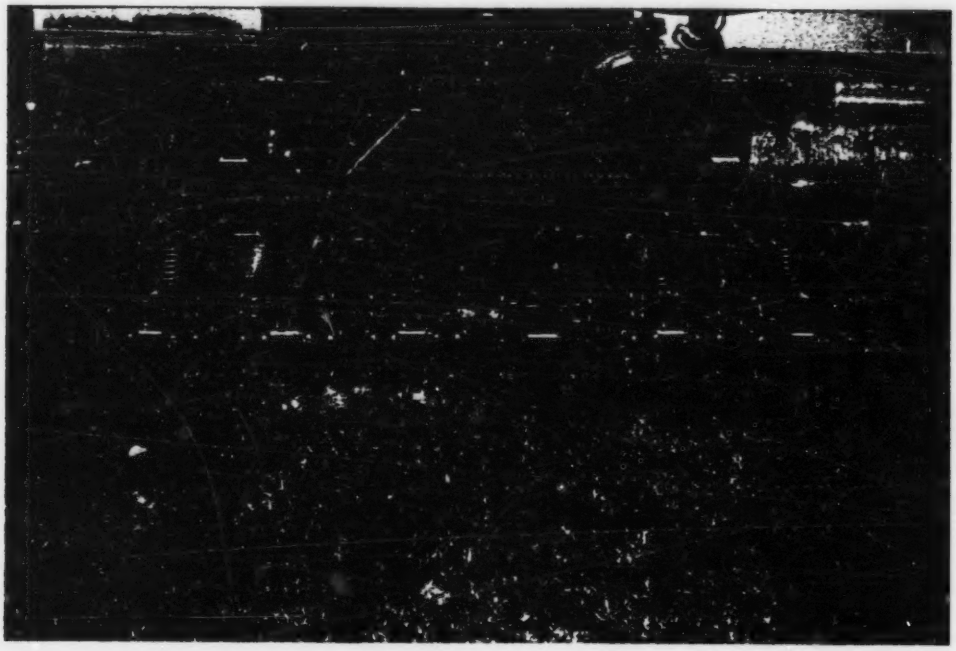

Figure 7. Tremuende, April 28, 1998. 3,300 gpa Applied.

Figure 8. Tremuende, April 28, 1998. 6,600 gpa Applied.

Figure 9. Tremuende, April 28, 1998. 13,300 gpa Applied.

Figure 10. Tremuende, September 30, 1998. After Full Application of 6,600 gpa. Note areas Sampled for Forage Yield.

Figure 11. Tremuende, October 20, 1998. Site Before Fall Applying.

6. Innovation Fund Acknowledgement

The sites have been marked with signs acknowledging AFIF support and funding of the project. Special attention was given to acknowledge AFIF support during all tours of the research sites.

AFIF support and funding have been acknowledged in all publications and presentations, and this will be continued.

7. Project Public Information Materials

The results of this project have already been presented at soils and crops workshops and press releases have highlighted the results. A copy of a published paper is attached in **Appendix II**.

A PAMI Research Update is now being prepared, which will be available in hard copy and available to download from the PAMI web site.

8. Expense Statement

The following table presents an expense statement for costs incurred to date.

Table 2. Expense Statement Costs.

Category	Year-to-Date Cost
PAMI	
Travel and Mileage	$ 3,927.60
Tractor Fuel	432.93
Tractor Lease	1,959.26
Shop Supplies	400.76
Transporting Equipment	6,593.20
Manure Hauling	1,650.00
Photographic Supplies	124.64
PAMI Personnel	45,895.50
PAMI Total	**$ 60,983.89**
Sask. Forage Council	**45,300.00**
U of S Soil Science	**27,400.00**
Total	**$133,683.89**

Distribution of costs to PAMI and other to the date of this report are:

PAMI - $ 60,983.89
SFC - 45,300.00
U of S - 27,400.00
Total - $133,683.89

PAMI is responsible to carry out all of the project with the subcontracts to Saskatchewan Forage Council and University of Saskatchewan for the maximum totals as paid. Some costs are still on-going, as final reporting and development of a publication, etc., will be carried out at PAMI's cost.

Appendix I

Project Data

Table 1. Application Sequence.

Location/Crop	1997		1998		1999	
	Spring	Fall	Spring	Fall	Spring	Fall
Englefeld, SK Crested Wheatgrass		37,000 L/ha 74,000 L/ha 148,000 L/ha		37,000 L/ha		37,000 L/ha 74,000 L/ha
Burr, SK Smooth Bromegrass/Alfalfa		37,000 L/ha 74,000 L/ha 148,000 L/ha		37,000 L/ha		37,000 L/ha 74,000 L/ha
Lanigan, SK Russian Wild Rye			37,000 L/ha 74,000 L/ha 148,000 L/ha	37,000 L/ha		37,000 L/ha 74,000 L/ha

Table 2.

1998 Low Disturbance Injection of Swine Manure into Forages
Partners (PAMI, Soil Science – University of Saskatchewan and Saskatchewan Forage Council)
Project Funded by AFIF

Soil Nutrient Application Rates, Biomass and Seed Yield, Quality and Plant N Uptake

Englefeld Saskatchewan – Crested Wheatgrass Cut on June 16th, 1998 (Belvedere Farms)

Manure Rate Fall 1997	Manure N and P Applied (kg/ha)				Biomass	Seed	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate (NO_3)
	Total N	Total NH_4-N	Total P	Total K	kg/ha	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	1000	20	30	56	11	18	0.00
Disturbed Check	0	0	0	0	930	16	30	56	12	18	0.00
37,000 L/ha (3,300 gal/acre)	105	93	6	38	2400	160	28	55	14	54	0.00
74,000 L/ha (6,600 gal/acre)	210	186	12	76	4390	210	31	57	12	84	0.01
*148,000 L/ha (13,200 gal/acre)	420	371	25	152	4300	300	29	56	12	83	0.05
Mean					2600	140	30	56	12	50	0.01
CV					17	57	13	4	17	21	10
LSD					890	149	ns	ns	ns	16	ns

Burr, Saskatchewan – Smooth Brome and Alfalfa cut on June 16th, 1998

Manure Rate Fall 1997	Manure N and P Applied (kg/ha)				Biomass	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate (NO_3)
	Total N	Total NH_4-N	Total P	Total K	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	1650	24	56	12	32	0.01
Disturbed Check	0	0	0	0	1310	22	56	13	27	0.01
37,000 L/ha (3,300 gal/acre)	81	65	6	38	2280	21	57	13	47	0.01
74,000 L/ha (6,600 gal/acre)	162	129	12	76	2760	18	55	15	66	0.03
*148,000 L/ha (13,200 gal/acre)	324	259	23	152	2460	18	54	16	63	0.07
Mean					2090	21	56	14	47	0.03
CV					11	11	4	8	15	2
LSD					470	5	ns	2	11	0.03

Lanigan, Saskatchewan – Russian Wild Ryegrass cut on July 8th, 1998 (Tremuende Farm)

Manure Rate Spring 1998	Manure N and P Applied (kg/ha)				Biomass	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate (NO_3)
	Total N	Total NH_4-N	Total P	Total K	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	2250	26	50	23	80	0.04
Disturbed Check	0	0	0	0	2030	25	47	25	79	0.02
37,000 L/ha (3,300 gal/acre)	90	72	4	43	2680	25	47	25	105	0.20**
74,000 L/ha (6,600 gal/acre)	180	144	8	86	3360	26	49	23	123	0.60**
*148,000 L/ha (13,200 gal/acre)	360	288	16	172	3110	24	48	25	121	1.10**
Mean					2690	25	48	24	102	0.40
CV					18	5	12	14	19	4
LSD					930	ns	ns	ns	30	0.30

* Note: This treatment was only applied once and that was in the fall of 1997 at Englefeld and Burr, and in the spring of 1998 at Lanigan.

** At levels of 0.15 to 0.45%, the feed may become dangerous for animals.

** At levels above 0.45%, the feed is potentially toxic and is not recommended for use as feed.

Table 3.

1999 Low Disturbance Injection of Swine Manure into Forages
Partners (PAMI, Soil Science – University of Saskatchewan and Saskatchewan Forage Council)
Project Funded by AFIF

Soil Nutrient Application Rates, Biomass and Seed Yield, Quality and Plant N Uptake

Englefeld Saskatchewan – Crested Wheatgrass Cut on June 18th, 1999 (Belvedere Farms)

Manure Rate Fall 1998	Manure N and P Applied (kg/ha)				Biomass	Seed	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate (NO_3)
	Total N	Total NH_4-N	Total P	Total K	kg/ha	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	1400	18	30	54	10	23	0.01
Disturbed Check	0	0	0	0	840	22	32	55	10	14	0.02
37,000 L/ha (3,300 gal/acre)	140	100	15	68	4460	178	31	57	12	86	0.01
74,000 L/ha (6,600 gal/acre)	0	0	0	0	2970	60	34	57	11	50	0.01
*148,000 L/ha (13,200 gal/acre)	0	0	0	0	3170	132	32	57	12	61	0.02
Mean					2570	82	32	56	11	47	0.02
CV					21	30	13	5	12	27	50
LSD					820	37	ns	ns	ns	20	ns

Burr, Saskatchewan – Smooth Brome and Alfalfa cut on June 30th, 1999

Manure Rate Fall 1998	Manure N and P Applied (kg/ha)				Biomass	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate (NO_3)
	Total N	Total NH_4-N	Total P	Total K	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	5010	28	56	12	96	0.02
Disturbed Check	0	0	0	0	4300	26	54	12	84	0.03
37,000 L/ha (3,300 gal/acre)	100	64	5	50	10600	26	56	11	184	0.03
74,000 L/ha (6,600 gal/acre)	0	0	0	0	8820	27	57	11	153	0.03
*148,000 L/ha (13,200 gal/acre)	0	0	0	0	10000	28	58	12	186	0.03
Mean					7760	27	56	12	141	0.03
CV					19	6	3	11	17	35
LSD					2220	ns	ns	ns	37	ns

Lanigan, Saskatchewan – Russian Wild Ryegrass cut on June 30th, 1999 (Tremuende Farm)

Manure Rate Fall 1998	Manure N and P Applied (kg/ha)				Biomass	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate (NO_3)
	Total N	Total NH_4-N	Total P	Total K	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	2170	30	54	15	53	0.02
Disturbed Check	0	0	0	0	2810	32	55	13	56	0.01
37,000 L/ha (3,300 gal/acre)	100	81	5	48	5460	31	57	16	139	0.02
74,000 L/ha (6,600 gal/acre)	0	0	0	0	5020	34	57	13	105	0.01
*148,000 L/ha (13,200 gal/acre)	0	0	0	0	5510	32	57	11	96	0.02
Mean					4190	32	56	14	90	0.01
CV					9	13	5	13	20	25
LSD					590	ns	ns	3	29	ns

* Note: This treatment was only applied once and that was in the fall of 1997 at Englefeld and Burr, and in the spring of 1998 at Lanigan.

Table 4.

2000 Low Disturbance Injection of Swine Manure into Forages
Partners (PAMI, Soil Science – University of Saskatchewan and Saskatchewan Forage Council)
Project Funded by AFIF

Soil Nutrient Application Rates, Biomass and Seed Yield, Quality and Plant N Uptake

Englefeld Saskatchewan – Crested Wheatgrass Cut on July 11th, 2000 (Belvedere Farms)

Manure Rate Fall 1999	Manure N and P Applied (kg/ha)				Biomass	Seed	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate (NO_3)
	Total N	Total NH_4-N	Total P	Total K	kg/ha	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	470	1	37	60	10	8	0.02
Disturbed Check	0	0	0	0	340	4	36	60	10	6	0.02
37,000 L/ha (3,300 gal/acre)	118	99	11	59	1380	126	30	57	13	30	0.03
74,000 L/ha (6,600 gal/acre)	236	198	22	118	2400	185	31	58	12	51	0.03
*148,000 L/ha (13,200 gal/acre)	0	0	0	0	770	5	37	61	10	13	0.02
Mean					1080	82	34	59	11	22	0.02
CV					15	51	8	2	18	35	75
LSD					250	51	4	2	ns	12	ns

Burr, Saskatchewan – Smooth Brome and Alfalfa cut on July 11th, 2000

Manure Rate Fall 1999	Manure N and P Applied (kg/ha)				Biomass	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate (NO_3)
	Total N	Total NH_4-N	Total P	Total K	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	1830	35	62	8	26	0.02
Disturbed Check	0	0	0	0	1850	35	62	8	26	0.02
37,000 L/ha (3,300 gal/acre)	89	69	4	50	3760	31	60	10	67	0.04
74,000 L/ha (6,600 gal/acre)	178	138	8	100	4480	32	61	11	83	0.04
*148,000 L/ha (13,200 gal/acre)	0	0	0	0	2400	34	61	8	36	0.02
Mean					2870	33	61	9	48	0.03
CV					12	10	4	6	14	31
LSD					540	ns	ns	1	10	ns

Lanigan, Saskatchewan – Russian Wild Ryegrass cut on July 11th, 2000 (Tremuende Farm)

Manure Rate Fall 1999	Manure N and P Applied (kg/ha)				Biomass	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate (NO_3)
	Total N	Total NH_4-N	Total P	Total K	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	1250	38	65	15	31	0.01
Disturbed Check	0	0	0	0	990	36	64	15	26	0.02
37,000 L/ha (3,300 gal/acre)	112	76	12	53	2900	34	62	16	82	0.02
74,000 L/ha (6,600 gal/acre)	224	152	24	106	3040	32	60	19	100	0.04
*148,000 L/ha (13,200 gal/acre)	0	0	0	0	1630	35	62	16	46	0.02
Mean					1960	35	63	16	57	0.02
CV					23	5	3	6	20	86
LSD					660	3	3	2	17	ns

* Note: This treatment was only applied once and that was in the fall of 1997 at Englefeld and Burr, and in the spring of 1998 at Lanigan.

Table 5.

1998 Low Disturbance Injection of Swine Manure into Forages
Partners (PAMI, Soil Science – University of Saskatchewan and Saskatchewan Forage Council)
Project Funded by AFIF

Soil Sample Analysis (kg/ha)

Englefeld (Belvedere Farms) Manure Rate in the Fall of 1997	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3	Spring Soil Available P
	0 – 30 cm	30 – 60 cm	0 – 30 cm	30 – 60 cm	0 – 60 cm	0 – 30 cm
Undisturbed Check (0 kg/ha N)	3	0.4	2	1	11	32
Disturbed Check (0 kg/ha N)	0	0.4	2	1	9	26
37,000 L/ha (Every year 97, 98, 99)	6	0.4	2	1	17	32
74,000 L/ha (Every second 97 and 99)	40	0.3	6	1	11	31
*148,000 L/ha (97 only)	85	0.4	5	1	14	26
Mean	27	0.4	3	1	12	29
LSD	41	ns	3	ns	5	12
Burr, Saskatchewan Manure Rate in the Fall of 1997	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3	Spring Soil Available P
	0 – 30 cm	30 – 60 cm	0 – 30 cm	30 – 60 cm	0 – 60 cm	0 – 30 cm
Undisturbed Check (0 kg/ha N)	16	1	7	8	9	33
Disturbed Check (0 kg/ha N)	6	1	4	6	9	20
37,000 L/ha (Every year 97, 98, 99)	32	1	8	5	10	48
74,000 L/ha (Every second 97 and 99)	43	3	10	6	14	17
*148,000 L/ha (97 only)	59	4	4	7	10	13
Mean	31	2	7	6	11	26
LSD	52	ns	4	ns	ns	ns
Lanigan, Saskatchewan Manure Rate in the Spring of 1998	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3	Spring Soil Available P
	0 – 30 cm	30 – 60 cm	0 – 30 cm	30 – 60 cm	0 – 60 cm	0 – 30 cm
Undisturbed Check (0 kg/ha N)	14	0	4	7	21	26
Disturbed Check (0 kg/ha N)	9	1	6	14	15	24
37,000 L/ha (Every year 97, 98, 99)	22	1	4	18	39	28
74,000 L/ha (Every second 97 and 99)	105	2	8	17	36	21
*148,000 L/ha (97 only)	18	3	9	9	73	20
Mean	34	2	6	13	37	24
LSD	66	ns	ns	ns	41.3	ns

*Note: This treatment was only applied once throughout the duration of this study. Once only in the fall of 1997 at Englefeld and Burr, and once only in the spring of 1998 at Lanigan.

Table 6.

1999 Low Disturbance Injection of Swine Manure into Forages
Partners (PAMI, Soil Science – University of Saskatchewan and Saskatchewan Forage Council)
Project Funded by AFIF

Soil Sample Analysis (kg/ha)

Englefeld (Belvedere Farms)	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3	Spring Soil Available P	Spring Soil Available K
Manure Rate in the Fall of 1998	0 – 30 cm	30 – 60 cm	0 – 30 cm	30 – 60 cm	0 – 60 cm	0 – 30 cm	0 – 30 cm
Undisturbed Check (0 kg/ha N)	4	3	8	7	3	12	826
Disturbed Check (0 kg/ha N)	3	2	5	5	3	10	817
37,000 L/ha (Every year 97, 98, 99)	21	2	10	6	5	11	919
74,000 L/ha (Every second 97 and 99)	4	2	9	4	5	10	1035
*148,000 L/ha (97 only)	4	2	7	4	3	10	942
Mean	7	2	8	5	4	10	908
LSD	ns	ns	ns	ns	ns	ns	ns
Burr, Saskatchewan	**Spring Soil NO_3**		**Spring Soil NH_4**		**Fall Soil NH_4 and NO_3**	**Spring Soil Available P**	**Spring Soil Available K**
Manure Rate in the Fall of 1998	**0 – 30 cm**	**30 – 60 cm**	**0 – 30 cm**	**30 – 60 cm**	**0 – 60 cm**	**0 – 30 cm**	**0 – 30 cm**
Undisturbed Check (0 kg/ha N)	7	3	9	4	6	10	884
Disturbed Check (0 kg/ha N)	6	2	5	6	11	8	651
37,000 L/ha (Every year 97, 98, 99)	33	2	7	4	8	8	786
74,000 L/ha (Every second 97 and 99)	4	8	4	3	6	8	769
*148,000 L/ha (97 only)	6	2	6	3	7	8	780
Mean	11	3	6	4	8	8	774
LSD	ns	4	ns	ns	4	ns	ns
Lanigan, Saskatchewan	**Spring Soil NO_3**		**Spring Soil NH_4**		**Fall Soil NH_4 and NO_3**	**Spring Soil Available P**	**Spring Soil Available K**
Manure Rate in the Fall of 1998	**0 – 30 cm**	**30 – 60 cm**	**0 – 30 cm**	**30 – 60 cm**	**0 – 60 cm**	**0 – 30 cm**	**0 – 30 cm**
Undisturbed Check (0 kg/ha N)	9	2	8	6	9	13	1600
Disturbed Check (0 kg/ha N)	10	2	8	4	9	11	1818
37,000 L/ha (Every year 97, 98, 99)	81	4	10	9	14	19	1918
74,000 L/ha (Every second 97 and 99)	13	3	9	9	11	11	1640
*148,000 L/ha (97 only)	13	3	10	9	12	11	1291
Mean	25	3	9	7	11	13	1653
LSD	30	ns	ns	4	4	5	540

*Note: This treatment was only applied once throughout the duration of this study. Once only in the fall of 1997 at Englefeld and Burr, and once only in the spring of 1998 at Lanigan.

Table 7.

2000 Low Disturbance Injection of Swine Manure into Forages
Partners (PAMI, Soil Science – University of Saskatchewan and Saskatchewan Forage Council)
Project Funded by AFIF

Soil Sample Analysis (kg/ha)

Englefeld (Belvedere Farms)	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3		Spring Soil Available P	Spring Soil Available K
Manure Rate in the Fall of 1999	0 – 30 cm	30 – 60 cm	0 – 30 cm	30 – 60 cm	0 – 60 cm	60 – 90 cm	0 – 30 cm	0 – 30 cm
Undisturbed Check (0 kg/ha N)	5	2	12	11	3.6	0.8	9	770
Disturbed Check (0 kg/ha N)	4	3	12	12	3.9	0.6	8	780
37,000 L/ha (Every year 97, 98, 99)	21	4	19	17	6.0	9.0	10	981
	55	4	37	12	4.2	1.4	11	943
74,000 L/ha (Every second 97 and 99)	6	2	13	9	5.4	0.7	8	789
*148,000 L/ha (97 only)								
Mean	18	3	19	12	4.6	2.5	9	853
LSD	24	2	13	6	2.0	4.7	2	200
Burr, Saskatchewan	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3		Spring Soil Available P	Spring Soil Available K
Manure Rate in the Fall of 1999	0 – 30 cm	30 – 60 cm	0 – 30 cm	30 – 60 cm	0 – 60 cm	60 – 90 cm	0 – 30 cm	0 – 30 cm
Undisturbed Check (0 kg/ha N)	3	2	11	10	3.3	2.0	6	834
Disturbed Check (0 kg/ha N)	3	1	12	15	2.8	7.9	6	727
37,000 L/ha (Every year 97, 98, 99)	41	4	40	17	3.8	2.4	7	791
	51	3	38	11	5.9	1.3	7	933
74,000 L/ha (Every second 97 and 99)	4	5	13	10	4.3	1.3	8	733
*148,000 L/ha (97 only)								
Mean	20	3	23	13	4.0	3.0	7	804
LSD	24	2	13	6	2.0	4.7	2	200
Lanigan, Saskatchewan	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3		Spring Soil Available P	Spring Soil Available K
Manure Rate in the Fall of 1999	0 – 30 cm	30 – 60 cm	0 – 30 cm	30 – 60 cm	0 – 60 cm	60 – 90 cm	0 – 30 cm	0 – 30 cm
Undisturbed Check (0 kg/ha N)	5	1	10	8	4.1	3.1	9	1785
Disturbed Check (0 kg/ha N)	5	1	10	8	4.4	2.5	9	1726
37,000 L/ha (Every year 97, 98, 99)	12	2	14	9	5.7	2.8	11	1756
	75	4	14	11	6.6	4.1	11	1871
74,000 L/ha (Every second 97 and 99)	7	2	10	10	5.5	3.3	8	1448
*148,000 L/ha (97 only)								
Mean	21	2	12	9	5.3	3.2	10	1717
LSD	24	2	13	6	2.0	4.7	2	200

*Note: This treatment was only applied once throughout the duration of this study. Once only in the fall of 1997 at Englefeld and Burr, and once only in the spring of 1998 at Lanigan.

Appendix II

Technical Paper

Shallow Injection of Hog Manure into Grassland

R. Pastl (Sask. Forage Council), G. Hultgreen (PAMI, Humboldt) and
J. Schoenau and S.P. Mooleki (Soil Science Dept. U of S)

Introduction

With the expected increase in hog production in Saskatchewan, concern has risen regarding the availability of sufficient land to utilize the manure resource to its full potential as a source of plant nutrients. Increases in inorganic fertilizer costs and concerns about the environmental effects of alternative manure disposal methods have stimulated interest in the use of livestock manure as a plant nutrient source (Hoff , Nelson and Sutton, 1981). Liquid hog manure is a valuable plant nutrient source, which is best perceived as a dilute multi-nutrient solution fertilizer blend. Therefore, application rates in the order of several thousand liters per hectare are required to meet the nutrient requirements of the crop versus 90 to 200 liters per hectare for concentrated commercial solution fertilizer blends (Schoenau, 1997). Ammonia-N losses from livestock manure have been reported to range from 10 to 90% when surface-applied to the soil (Vanderholm, 1975). Hoff, Nelson and Sutton, (1981) showed that 14 to 65% of the ammonia-N was lost over a 3.5 day period, when the hog manure was broadcast on the soil surface. However, if the hog manure was injected, the ammonia-N losses were reduced to 2.5% or less. Hoff, Nelson and Sutton, (1981) suggested that injecting hog manure into the soil would maximize the nutrient value of the hog manure as a fertilizer and would minimize surface water and atmospheric N contamination. There currently is little information on the plant and soil response to injection of hog manure into grasslands on the Canadian prairies. The objectives of the study are (1) to evaluate the practicality of shallow injection of hog manure into typical grassland stands in Saskatchewan (2) to determine the effect hog manure has on forage yield, forage quality and forage nitrate levels at various application rates (3) and to determine the effect on soil nutrients under various hog manure application rates.

Methodology

The study is a three-year project (1998-2000). A low disturbance injection system based on coulter type openers with hoses running to each opener was used to inject liquid hog manure 10 to 13 cm (4 to 5 inches) into mature grass stands. The coulters were arranged to inject hog manure on 30 cm (12 inch) row spacing. Liquid hog manure was injected into crested wheatgrass (Englefeld, Sask.) and smooth bromegrass/alfalfa stands (Burr, Sask.) in the fall of 1997 and into a Russian wild-rye stand (Lanigan, Sask.) in April 1998. Liquid hog manure was injected again at all sites in the fall of 1998 and 1999.

Manure was hauled to each site from a nearby earthen manure storage unit. Three 10 litre samples of hog manure were collected from the applicator during application and analyzed for nitrogen, phosphorus and potassium content. In September 1997, at Englefeld and Burr, the hog manure application rates were 37,000 L/ha (3300 gal/acre), 74,000 L/ha (6600 gal/acre) and 148,000 L/ha (13200 gal/acre). At Lanigan, the same application rates were applied in April 1998. In October of 1998, liquid hog manure was applied at 37,000

L/ha (3300 gal/acre) at all locations. It should be noted that the 74,000 L/ha rate (6600 gal/acre) and the 148,000 L/ha (13200 gal /acre) rates were not applied in the fall of 1998. In October of 1999, liquid hog manure was injected at 37,000 L/ha (3300 gal/acre) and at 74,000 L/ha (6600 gal/acre) at all sites. It should also be noted that the 148,000 L/ha (13200 gal /acre) application rate was not applied in the fall of 1999. The 148,000 L/ha (13200 gal /acre) rate was only applied once (fall of 1997) throughout the course of this study. Based on nutrient analysis of the hog manure samples, the calculated rate of applied plant nutrients is shown in tables 1, 2 and 3, for each year and site.

Two Controls were used: a disturbed check passing over the plot with the injector to produce soil disturbance similar to the treatments, but with out injecting hog manure and an undisturbed check. The disturbed check was applied each year throughout the course of this study when the other treatments were applied. The experimental design was a randomized complete block design, replicated four times. The grasses were harvested just after heading was complete, in mid-June and early July 1998, 1999 and 2000. Four, 1.2 m x 6 m samples were cut from each plot and weighed to determine fresh yield/plot. During the harvest operation, grab samples were collected at random from each plot at each location and used to correct yields to a dry weight basis and to determine the crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and the nitrate content of the forage for each treatment. In August of 1998, two, one-quarter meter samples were collected per plot from the crested wheatgrass site at Englefeld and used to determine the seed yield. In 1999 and 2000, three one-half meter squared samples were collected from each plot at the Englefeld site and used to determine the crested wheatgrass seed yield. Soil samples were collected in April and September from each plot each year (0-30 cm, 30-60 cm) and analyzed for ammonium, nitrate and extractable phosphorus and potassium.

Results and Discussion

The application equipment was effective in injecting the hog manure at the desired depth with low disturbance and minimal stand injury as shown by the small difference in yield between the undisturbed and disturbed controls (Tables 1 and 2.). In 1998, when liquid hog manure was injected at 74,000 L/ha (6,600 gal/acre) crested wheatgrass forage yield (Englefeld site) increased from 1,000 to 4,390 kg/ha, Russian wild-rye yields (Lanigan site) increased from 2,250 to 3,360 kg/ha and smooth brome/alfalfa yields (Burr site) increased from 1,650 to 2,760 kg/ha over the undisturbed control (Table 1.). In addition, the seed yield of crested wheat grass increased from 20 to 210 kg/ha. Overall, in 1998, grass biomass yield appeared to be maximized at rates of total hog manure N, between 100-200 kg total N/ha (37,000 – 74,000 L/ha). The crested wheatgrass site was most responsive to manure in terms of percentage yield increase over the control, while Russian wild-rye was the least responsive and smooth brome/alfalfa was intermediate.

In 1999, when liquid hog manure was injected once again in the fall of 1998 at 37,000 L/ha (3,300 gal/acre) crested wheatgrass forage yield (Englefeld site) increased from 1,400 to 4,460 kg/ha, Russian wild-rye yields (Lanigan site) increased from 2,170 to 5,460 kg/ha and

smooth brome/alfalfa yields (Burr site) increased from 5,010 to 10,600 kg/ha over the undisturbed control (Table 2.). In addition, the seed yield of crested wheat grass increased from 18 to 178 kg/ha. Overall, in 1999, significant yield increases occurred from a single larger application of manure made in the first year of this study. At all sites, medium 74,000 L/ha (6,600 gal/acre) and high application 148,000 L/ha (13200 gal/acre) had enough residual carryover to produce significantly higher forage yields than the control the next year. In year two, yields obtained from the single larger application rates made in year one were close to those obtained from the smaller 37,000 L/ha (3,300 gal/acre) applications applied both years (Table 2.).

In 2000, when liquid hog manure was injected once again in the fall of 1999 at 37,000 L/ha (3,300 gal/acre) and 74,000 L/ha (6600 gal/acre) crested wheatgrass forage yield (Englefeld site) increased from 470 to 1380 and 2400 kg/ha, respectively. The Russian wild-rye yields (Lanigan site) increased from 1830 to 3760 and 4480 kg/ha, respectively. At the same time, the smooth brome/alfalfa yields (Burr site) increased from 1250 to 2900 and 3040 kg/ha, over the undisturbed control (Table 3.). In addition, the seed yield of crested wheat grass increased from 1 to 126 and 185 kg/ha. The residual nutrient effect of the high rate (148,000 L/ha) applied once at the start of the study has clearly diminished by year 3 (2000), although yields are still significantly higher than the control.

Overall, in 1998, the injection of hog manure increased the forage seed and feed yield as the rate of hog manure increased from zero to 74,000 L/ha (6600 gal/acre). In 1999, significant yield increases occurred from a single larger application of manure made in the first year of this study. At all sites, medium 74,000 L/ha (6,600 gal/acre) and high application 148,000 L/ha (13200 gal/acre) had enough residual carryover to produce significantly higher forage yields than the control the next year. In year two, yields obtained from the single application rates made in year one were close to those obtained from the smaller 37,000 L/ha (3,300 gal/acre) yearly application rates (Table 2.). In year three, the single application rate of 148,000 L/ha (13200 gal/acre) made in the fall of 1997, provided enough carry over nutrient to the soil to significantly out yield the controls at Englefeld and Burr, but not at Lanigan (Table 3.). In terms of crested wheatgrass seed yields, the one time application of 148,000 L/ha (13200 gal/acre) made in the fall of 1997, did not provide enough carry over nutrients to significantly out yield the controls at Englefeld. At all sites, the 74,000 L/ha (6600 gal/acre) application rate made in the fall of 1999, out yielded all other application rates (Table 3.). It should also be noted that the forage yield in 2000 at all sites and for treatments were lower than in the two previous years, reflecting the cool spring conditions which limited forage growth.

Table 1.

1998 Low Disturbance Injection of Swine Manure into Forages

Partners (PAMI, Soil Science - UofS and Sask. Forage Council)

Project Funded by AFIF

Soil Nutrient Application Rates, Biomass and Seed Yield, Quality and Plant N uptake

Englefeld Saskatchewan - Crested Wheatgrass Cut on June 16, 1998 (Belvedere Farms)

Manure Rate Fall 1997	Manure N and P Applied (kg/ha)				Biomass	Seed	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate (NO_3)
	Total N	Total NH_4-N	Total P	Total K	kg/ha	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	1000	20	30	56	11	18	0
Disturbed Check	0	0	0	0	930	16	30	56	12	18	0
37,000 l/ha (3300 gal/acre)	105	93	6	38	2400	160	28	55	14	54	0
74,000 l/ha (6600 gal/acre)	210	186	12	76	4390	210	31	57	12	84	0.01
*148,000 l/ha (13,200 gal/acre)	420	371	25	152	4300	300	29	56	12	83	0.05
Mean					2600	140	30	56	12	50	0.01
CV					17	57	13	4	17	21	10
LSD					890	149	ns	ns	ns	16	ns

Burr, Saskatchewan - Smooth Brome and Alfalfa cut on June 16, 1998

Manure Rate Fall 1997	Manure N and P Applied (kg/ha)				Biomass		ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate
	Total N	Total NH_4-N	Total P	Total K	kg/ha		%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	1650		24	56	12	32	0.01
Disturbed Check	0	0	0	0	1310		22	56	13	27	0.01
37,000 l/ha (3300 gal/acre)	81	65	6	38	2280		21	57	13	47	0.01
74,000 l/ha (6600 gal/acre)	162	129	12	76	2760		18	55	15	66	0.03
*148,000 l/ha (13,200 gal/acre)	324	259	23	152	2460		18	54	16	63	0.07
Mean					2090		21	56	14	47	0.03
CV					11		11	4	8	15	2
LSD					470		5	ns	2	11	0.03

Lanigan, Saskatchewan - Russian Wild Ryegrass cut on July 8th, 1998 (Tremuende Farm)

Manure Rate Spring 98	Manure N and P Applied (kg/ha)				Biomass		ADF	NDF	Crude Protein	Plant N Uptake	Nitrate % Nitrate
	Total N	Total NH_4-N	Total P	Total K	kg/ha		%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	2250		26	50	23	80	0.04
Disturbed Check	0	0	0	0	2030		25	47	25	79	0.02
37,000 l/ha (3300 gal/acre)	90	72	4	43	2680		25	47	25	105	0.20
74,000 l/ha (6600 gal/acre)	180	144	8	86	3360		26	49	23	123	0.60
*148,000 l/ha (13,200 gal/acre)	360	288	16	172	3110		24	48	25	121	1.10
Mean					2690		25	48	24	102	0.40
CV					18		5	12	14	19	4
LSD					930		ns	ns	ns	30	0.30

*Note: This treatment was only applied once and that was in the fall of 1997 at Englefeld and Burr; in the spring of 1998 at Lanigan.

Table 2.

1999 Low Disturbance Injection of Swine Manure into Forages

Partners (PAMI, Soil Science - UofS and Sask. Forage Council)
Project Funded by AFIF

Soil Nutrient Application Rates, Biomass and Seed Yield, Quality and Plant N uptake

Englefeld Saskatchewan - Crested Wheatgrass Cut on June 18th, 1999 (Belvedere Farms)

Manure Rate	Manure N and P Applied (kg/ha)				Biomass	Seed	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate $_{(NO_3)}$
Fall 1998	Total N	Total NH_4 - N	kg P/ha	kg K/ha	kg/ha	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	1400	18	30	54	10	23	0.01
Disturbed Check	0	0	0	0	840	22	32	55	10	14	0.02
37,000 l/ha (3300 gal/acre)	140	100	15	68	4460	178	31	57	12	86	0.01
74,000 l/ha (6600 gal/acre)	0	0	0	0	2970	60	34	57	11	50	0.01
*148,000 l/ha (13,200 gal/acre)	0	0	0	0	3170	132	32	57	12	61	0.02
Mean					2570	82	32	56	11	47	0.02
CV					21	30	13	5	12	27	50
LSD					820	37	ns	ns	ns	20	ns

Burr, Saskatchewan - Smooth Brome and Alfalfa cut on June 30th, 1999

Manure Rate	Manure N and P Applied (kg/ha)				Biomass		ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate $_{(NO_3)}$
Fall 98	Total N	Total NH_4-N	Total P	Total K	kg/ha		%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	5010		28	56	12	96	0.02
Disturbed Check	0	0	0	0	4300		26	54	12	84	0.03
37,000 l/ha (3300 gal/acre)	100	64	5	50	10600		26	56	11	184	0.03
74,000 l/ha (6600 gal/acre)	0	0	0	0	8820		27	57	11	153	0.03
*148,000 l/ha (13,200 gal/acre)	0	0	0	0	10000		28	58	12	186	0.03
Mean					7760		27	56	12	141	0.03
CV					19		6	3	11	17	35
LSD					2220		ns	ns	ns	37	ns

Lanigan, Saskatchewan - Russian Wild Ryegrass cut on June 30th, 1999 (Tremuende Farm)

Manure Rate	Manure N and P Applied (kg/ha)				Biomass		ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate $_{(NO_3)}$
Fall 98	Total N	Total NH_4-N	Total P	Total K	kg/ha		%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	2170		30	54	15	53	0.02
Disturbed Check	0	0	0	0	2810		32	55	13	56	0.01
37,000 l/ha (3300 gal/acre)	100	81	5	48	5460		31	57	16	139	0.02
74,000 l/ha (6600 gal/acre)	0	0	0	0	5020		34	57	13	105	0.01
*148,000 l/ha (13,200 gal/acre)	0	0	0	0	5510		32	57	11	96	0.02
Mean					4190		32	56	14	90	0.01
CV					9		13	5	13	20	25
LSD					590		ns	ns	3	29	ns

*Note: This treatment was only applied once and that was in the fall of 1997 at Englefeld and Burr; in the spring of 1998 at Lanigan.

Table 3.

2000 Low Disturbance Injection of Swine Manure into Forages

Partners (PAMI, Soil Science - UofS and Sask. Forage Council)
Project Funded by AFIF

Soil Nutrient Application Rates, Biomass and Seed Yield, Quality and Plant N uptake

Englefeld Saskatchewan - Crested Wheatgrass Cut on July 11th, 2000 (Belvedere Farms)

Manure Rate	Manure N and P Applied (kg/ha)				Biomass	Seed	ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate $_{(NO_3)}$
Fall 1999	Total N	Total NH_4-N	kg P/ha	kg K/ha	kg/ha	kg/ha	%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	470	1	37	60	10	8	0.02
Disturbed Check	0	0	0	0	340	4	36	60	10	6	0.02
37,000 l/ha (3300 gal/acre)	118	99	11	59	1380	126	30	57	13	30	0.03
74,000 l/ha (6600 gal/acre)	236	198	22	118	2400	185	31	58	12	51	0.03
*148,000 l/ha (13,200 gal/acre)	-	-	-	-	770	5	37	61	10	13	0.02
Mean					1080	82	34	59	11	22	0.02
CV					15	51	8	2	18	35	75
LSD					250	51	4	2	ns	12	ns

Burr, Saskatchewan - Smooth Brome and Alfalfa cut on July 11th, 2000

Manure Rate	Manure N and P Applied (kg/ha)				Biomass		ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate $_{(NO_3)}$
Fall 99	Total N	Total NH_4-N	Total P	Total K	kg/ha		%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	1830		35	62	8	26	0.02
Disturbed Check	0	0	0	0	1850		35	62	8	26	0.02
37,000 l/ha (3300 gal/acre)	89	69	4	50	3760		31	60	10	67	0.04
74,000 l/ha (6600 gal/acre)	178	138	8	100	4480		32	61	11	83	0.04
*148,000 l/ha (13,200 gal/acre)	-	-	-	-	2400		34	61	8	36	0.02
Mean					2870		33	61	9	48	0.03
CV					12		10	4	6	14	31
LSD					540		ns	ns	1	10	ns

Lanigan, Saskatchewan - Russian Wild Ryegrass cut on July 11th, 2000 (Tremuende Farm)

Manure Rate	Manure N and P Applied (kg/ha)				Biomass		ADF	NDF	Crude Protein	Plant N Uptake	% Nitrate $_{(NO_3)}$
Fall 99	Total N	Total NH_4-N	Total P	Total K	kg/ha		%	%	%	kg/ha	Dry Sample
Undisturbed Check	0	0	0	0	1250		38	65	15	31	0.01
Disturbed Check	0	0	0	0	990		36	64	15	26	0.02
37,000 l/ha (3300 gal/acre)	112	76	12	53	2900		34	62	16	82	0.02
74,000 l/ha (6600 gal/acre)	224	152	24	106	3040		32	60	19	100	0.04
*148,000 l/ha (13,200 gal/acre)	-	-	-	-	1630		35	62	16	46	0.02
Mean					1960		35	63	16	57	0.02
CV					23		5	3	6	20	86
LSD					660		3	3	2	17	ns

*Note: This treatment was only applied once and that was in the fall of 1997 at Englefeld and Burr; in the spring of 1998 at Lanigan.

The effect of the manure on increasing N availability is shown in the increases in plant N uptake with manure application. There was a significant increase in plant N uptake at all locations and at all rates when compared to the control. Increases in grass yield and protein content are largely attributed to the effect of the manure in increasing soil N availability although other nutrients available in the liquid hog manure, such as P and K, may also have contributed to the yield increases. The amount of N uptake tended to increase with increase in hog manure application rate. In 1999, the 37,000 L/ha (3300 gal/acre) yearly application rate showed a significant increase in N uptake at Englefeld and Lanigan compared to the other applications rates (Table 2.). Data is not yet available for 2000.

In 1998, the Russian wild-rye and the smooth brome/alfalfa mix showed a significant increase in nitrate (NO_3) content of the forage when the hog manure was applied at the highest rate, (148,000 L/ha) (Tables 1.). Essig et al., (1993) indicated that a nitrate content of 0.0 – 0.15% is considered safe to feed under all conditions. A feed stuff with a nitrate content of between 0.15 – 0.45% varies from being safe to feed under most conditions to being dangerous to animal health. Feed stuffs with a nitrate content of over 0.45% are all potentially toxic and not recommended to be used as feed. The nitrate content of the smooth brome remained well within acceptable levels (Table 1.). However, at 148,000 L/ha, the nitrate concentration of the Russian wild-rye was more than seven times the acceptable levels (Table 1.). The higher nitrate content of the Russian wild rye may be related to the physiological and morphological characteristics of the plant. Crested wheatgrass and smooth brome have an up-right growth habit, with much more tillering and a higher nitrogen demand, resulting in greater incorporation of assimilated nitrogen into organic constituents. On the other hand, Russian wild-rye has a much more basal growth habit, producing a large number of dark green basal leafs, with few tillers developing. These large succulent leaves would accumulate nitrates, especially when moisture and nitrogen are readily available. On the other hand, in 1999 and 2000, all nitrate contents of the forages were well within acceptable limits, indicating that the nitrate content of the forage will vary from year to year and site to site, depending on the species being grown, environmental conditions and manure application rate (Tables 1., 2. and 3.). The most prudent producers will ensure that a proper forage quality analysis is carried out before any forage is used as a feed stuff.

In 1998 and 1999, spring soil samples indicated that hog manure application produced significant increases in plant available inorganic nitrogen (Tables 4. and 5.). The increases in available nitrogen, particularly nitrates, were most pronounced in the surface layer 0 –30 cm, with manure application having relatively little effect on available N contents in the 30 – 60 cm layer (Table 4. and 5.). The ammonium nitrogen applied as hog manure would have been assimilated by the grass roots, utilized by the soil microorganisms or possibly volatilized. Some of the organic N added in 1997 and 1998, would be mineralized and some would remain as organic N at the end of the season.

In 1998, the amount of inorganic N left in the soil profile in the fall manure treatments was only slightly and usually not significantly higher than the control at the crested wheatgrass and smooth brome/alfalfa sites (Table 4.). The high application rate in the

Russian wild-rye did produce substantially higher inorganic N levels in the soil in the fall, but the amounts were still less than 100 kg/ha (Table 4.) Similar results were obtained in 1999, when hog manure was injected at the 37,000 L/ha (3300 gal/acre) rate (Table 5.). There was no evidence of nitrogen leaching below the 30-cm depth in 1998, 1999 and 2000, for any of the treatments, and total N in the 0-60 cm depth, had reduced to less than 20 kg/ha by the fall of 1999 (Tables 4 and 5). In 2000, there was an increase in spring available N (NH_4 and NO_3) related to the manure application made the previous fall (Table 6.). This increase was mainly confined to the 0-30 cm layer. The large single application (148,000 L/ha) made in the fall of 1997 showed no significant increase in extractable inorganic N in the spring of 2000.

Manure application did not have a large influence on extractable inorganic phosphorus or potassium levels in the soil (Tables 4., 5. and 6.). The limited effect of the manure on the extractable P is consistent with the relatively low amounts of P applied as manure (Table 1,2 and 3) and P movement should not be a concern. Increases in extractable K with manure applications were observed, consistent with the relatively high amount of K added as manure. However, the extractable K is not sensitive enough to indicate significant differences in the majority of cases.

Hog manure application did not significantly affect the electrical conductivity of the soil or the soil pH (data not shown). However, all hog manure applied should be routinely tested for salt content and concentrations as part of the manure analysis. This should also be accompanied by regular monitoring of all fields where hog manure is applied to ensure that concentrations of salts and other nutrients are not building up in the soil.

TAble 4.

1998 Low Disturbance Injection of Swine Manure into Forages

Partners (PAMI, Soil Science - UofS and Sask. Forage Council)

Project Funded by AFIF

Soil Sample Analysis (kg/ha)

Englefeld (Belvedere Farms)	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3	Spring Soil Available P
Manure Rate in the Fall of 1997	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-60 cm	0-30 cm
Undisturbed Check (0 kg/ha N)	3	0.4	2	1	11	32
Disturbed Check (0 kg/ha N)	0	0.4	2	1	9	26
37,000 l/ha (Every year 97, 98, 99)	6	0.4	2	1	17	32
74,000 l/ha (Every second 97 and 99)	40	0.3	6	1	11	31
*148,000 l/ha (97 only)	85	0.4	5	1	14	26
Mean	27	0.4	3	1	12	29
LSD	41	ns	3	ns	5	12
Burr, Saskatchewan	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3	Spring Soil Available P
Manure Rate in the Fall of 1997	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-60 cm	0-30 cm
Undisturbed Check (0 kg/ha N)	16	1	7	8	9	33
Disturbed Check (0 kg/ha N)	6	1	4	6	9	20
37,000 l/ha (Every year 97, 98, 99)	32	1	8	5	10	48
74,000 l/ha (Every second 97 and 99)	43	3	10	6	14	17
*148,000 l/ha (97 only)	59	4	4	7	10	13
Mean	31	2	7	6	11	26
LSD	52	ns	4	ns	ns	ns
Lanigan (Tremuende Farm)	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3	Spring Soil Available P
Manure Rate in the Spring of 1998	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-60 cm	0-30 cm
Undisturbed Check (0 kg/ha N)	14	0	4	7	21	26
Disturbed Check (0 kg/ha N)	9	1	6	14	15	24
37,000 l/ha (Every year 97, 98, 99)	22	1	4	18	39	28
74,000 l/ha (Every second 97 and 99)	105	2	8	17	36	21
*148,000 l/ha (97 only)	18	3	9	9	73	20
Mean	34	2	6	13	37	24
LSD	66	ns	ns	ns	41.3	ns

*Note:This treatment was only applied once throughout the duration of this study.
Once only in the fall of 1997 at Englefeld and Burr; once only in the spring of 1998 at Lanigan.

Table 5.

1999 Low Disturbance Injection of Swine Manure into Forages
Partners (PAMI, Soil Science - UofS and Sask. Forage Council)
Project Funded by AFIF
Soil Sample Analysis (kg/ha)

Englefeld (Belvedere Farms)	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3	Spring Soil Available P	Spring Soil Available K
Manure Rate in the Fall of 1998	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-60 cm	0-30 cm	0-30 cm
Undisturbed Check (0 kg/ha N)	4	3	8	7	3	12	826
Disturbed Check (0 kg/ha N)	3	2	5	5	3	10	817
37,000 l/ha (Every year 97, 98, 99)	21	2	10	6	5	11	919
74,000 l/ha (Every second 97 and 99)	4	2	9	4	5	10	1035
*148,000 l/ha (97 only)	4	2	7	4	3	10	942
Mean	7	2	8	5	4	10	908
LSD	ns	ns	ns	ns	ns	ns	ns

Burr, Saskatchewan	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3	Spring Soil Available P	Spring Soil Available K
Manure Rate in the Fall of 1998	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-60 cm	0-30 cm	0-30 cm
Undisturbed Check (0 kg/ha N)	7	3	9	4	6	10	884
Disturbed Check (0 kg/ha N)	6	2	5	6	11	8	651
37,000 l/ha (Every year 97, 98, 99)	33	2	7	4	8	8	786
74,000 l/ha (Every second 97 and 99)	4	8	4	3	6	8	769
*148,000 l/ha (97 only)	6	2	6	3	7	8	780
Mean	11	3	6	4	8	8	774
LSD	ns	4	ns	ns	4	ns	ns

Lanigan (Tremuende Farm)	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3	Spring Soil Available P	Spring Soil Available K
Manure Rate in the Fall of 1998	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-60 cm	0-30 cm	0-30 cm
Undisturbed Check (0 kg/ha N)	9	2	8	6	9	13	1600
Disturbed Check (0 kg/ha N)	10	2	8	4	9	11	1818
37,000 l/ha (Every year 97, 98, 99)	81	4	10	9	14	19	1918
74,000 l/ha (Every second 97 and 99)	13	3	9	9	11	11	1640
*148,000 l/ha (97 only)	13	3	10	9	12	11	1291
Mean	25	3	9	7	11	13	1653
LSD	30	ns	ns	4	4	5	540

*Note:This treatment was only applied once throughout the duration of this study.
Once only in the fall of 1997 at Englefeld and Burr; once only in the spring of 1998 at Lanigan.

Table 6.

2000 Low Disturbance Injection of Swine Manure into Forages
Partners (PAMI, Soil Science - UofS and Sask. Forage Council)
Project Funded by AFIF
Soil Sample Analysis (kg/ha)

Englefeld (Belvedere Farms)	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3		Spring Soil Available P	Spring Soil Available K
Manure Rate in the Fall of 1999	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-60 cm	60-90 cm	0-30 cm	0-30 cm
Undisturbed Check (0 kg/ha N)	5	2	12	11	3.6	0.8	9	770
Disturbed Check (0 kg/ha N)	4	3	12	12	3.9	0.6	8	780
37,000 l/ha (Every year 97, 98, 99)	21	4	19	17	6.0	9.0	10	981
74,000 l/ha (Every second 97 and 99)	55	4	37	12	4.2	1.4	11	943
*148,000 l/ha (97 only)	6	2	13	9	5.4	0.7	8	789
Mean	18	3	19	12	4.6	2.5	9	853
LSD	24	2	13	6	2.0	4.7	2	200

Burr, Saskatchewan	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3		Spring Soil Available P	Spring Soil Available K
Manure Rate in the Fall of 1998	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-60 cm	60-90 cm	0-30 cm	0-30 cm
Undisturbed Check (0 kg/ha N)	3	2	11	10	3.3	2.0	6	834
Disturbed Check (0 kg/ha N)	3	1	12	15	2.8	7.9	6	727
37,000 l/ha (Every year 97, 98, 99)	41	4	40	17	3.8	2.4	7	791
74,000 l/ha (Every second 97 and 99)	51	3	38	11	5.9	1.3	7	933
*148,000 l/ha (97 only)	4	5	13	10	4.3	1.3	8	733
Mean	20	3	23	13	4.0	3.0	7	804
LSD	24	2	13	6	2.0	4.7	2	200

Lanigan (Tremuende Farm)	Spring Soil NO_3		Spring Soil NH_4		Fall Soil NH_4 and NO_3		Spring Soil Available P	Spring Soil Available K
Manure Rate in the Fall of 1998	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-60 cm	60-90 cm	0-30 cm	0-30 cm
Undisturbed Check (0 kg/ha N)	5	1	10	8	4.1	3.1	9	1785
Disturbed Check (0 kg/ha N)	5	1	10	8	4.4	2.5	9	1726
37,000 l/ha (Every year 97, 98, 99)	12	2	14	9	5.7	2.8	11	1756
74,000 l/ha (Every second 97 and 99)	75	4	14	11	6.6	4.1	11	1871
*148,000 l/ha (97 only)	7	2	10	10	5.5	3.3	8	1448
Mean	21	2	12	9	5.3	3.2	10	1717
LSD	24	2	13	6	2.0	4.7	2	200

*Note:This treatment was only applied once throughout the duration of this study.
Once only in the fall of 1997 at Englefeld and Burr; once only in the spring of 1998 at Lanigan.

Conclusion

Low disturbance injected hog manure was effective at increasing the forage yield of crested wheatgrass, smooth brome grass and Russian wild-rye. In 1998, yields were highest at the application rate of 73, 000 L/ha (6600 gal/acre). Applying hog manure at 148,000 L/ha in the spring of 1998 had a tendency to decrease yield over the medium rate and produced excessive tissue nitrate levels in the Russian wild-rye. In 1999, all sites, medium 74,000 L/ha (6,600 gal/acre) and high application rates 148,000 L/ha (13200 gal/acre) made once at the start of the 1998 season had enough residual carryover to produce significantly higher forage yields than the control. In addition, these rates yielded close to the smaller 37,000 L/ha (37,000 gal/acre) yearly application rate. In 2000, the 74,000 L/ha (6600 gal/acre) rate applied in the fall of 1999 resulted in the highest forage biomass at all locations and forage seed yields at Englefeld. The yields in plots treated with hog manure were 1.5 to 4 times higher than the control plots in all years and locations. Given the results of this study, the most economical application strategy may be to apply 74,000 L/ha (6600 gal/acre) every other year.

The smaller yearly application rate plots showed higher inorganic N levels in the soil in the spring of 1999 than the higher single rate treatments. Single application made at the start of 1998 even at the high rate, did not produce significantly higher soil profile inorganic N than the control in 1999, yet yielded significantly higher. Additional available nitrogen and forage response in 1999 and 2000 must have come from organic N mineralization in the higher single rate plots. Nearly all soil profile available N effects were restricted to the top 30 cm of soil and there was no evidence of deep leaching. Soil extractable P and K levels were similar among treatments. Grassland stands appear to be well suited for the practical application of hog manure in an environmentally friendly manner. Forage producers should ensure that a proper forage quality analysis is carried out before any forage is used as a feed source. In addition, the application of hog manure using a coultor applicator system did not increase the weed density of treated plots over the controls (visual observation). In fact, it appeared that the increased competition by the grass after hog manure application decreased the weed density in these plots compared to the controls. This was especially evident in the crested wheatgrass at Englefeld.

As a direct result of this study, a commercial coulter liquid hog manure applicator system has been developed by "Bourgeault Industries" of St. Bieux, Saskatchewan. This new application system will dramatically increase the land base suitable for liquid hog manure injection; it will provide a much longer window of application and reduce the likelihood of surface water contamination and nitrogen loss to the atmosphere. Previously, liquid hog manure was usually injected or broadcast directly on the soil surface in the spring and fall on land where the amount of soil disturbance was not a concern (usually a conventional annual cropping system). This effectively eliminated forage producers or zero-till producers unless they were willing to tolerate the soil disturbance resulting from injecting with shovels, or if the liquid hog manure was broadcast directly to the soil surface. The direct application of liquid hog manure to the soil surface has been shown by other researchers to greatly increase the likelihood of surface water contamination and nitrogen loss to the atmosphere.

Industry representatives have indicated the need to increase the amount of land available within the immediate vicinity of a hog barn. Some of the large hog operations require 10,000

acres or more each to apply liquid hog manure in an environmentally friendly manner. Forage and cattle producers have expressed a keen interest in entering contracts with the hog industry where the hog operation provides and applies the hog manure to the forage land to increase the carrying capacity of their land base. However, in 1998, the nitrate concentration increased in the smooth brome and Russian wildrye when the hog manure was applied at the 148,000 L/ha (13200 gal/acre) application rate (Table 1.). High nitrate concentrations in feed have been implicated in the sudden death of livestock animals (Merch and Co. Inc 1991). Some symptoms include rapid difficult breathing, anxiety, vomiting and diarrhea. As a result, the hog industry needs to know how soon cattle can be placed on land after the hog manure has been applied and do they have to be concerned about possible high nitrate contents of the forage. The livestock industry needs to know how soon after application they can expect an increase in the nitrate concentration; how much will it increase; how long the concentrations will remain and what forage species will be most affected by the application of liquid hog manure. At this point in time the data are not available to safely make a recommendation.

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